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Attachment C - FINAL Human Health and Ecological Risk Assessment Work Plan

August 2013

Commonwealth Oil Refining

Company, Inc.

Penuelas,

Puerto Rico

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1.0 INTRODUCTION

This Human Health and Ecological Risk Assessment Work Plan (HHERAWP) provides the data collection procedures to conduct a human health and ecological risk assessment investigation at multiple areas of Commonwealth Oil Refining Company Inc., (CORCO) located at Route 127, Municipio de Peñuelas, Puerto Rico (site). As described previously, in Section 4.0 the CORCO facility has been divided into 9 areas based facility operations (Figure 4-2 of the RFI Work Plan).

The human health and ecological risk assessments are designed to aid in risk management decisions regarding actions that may be necessary to address hazardous substances at the site. The approach presented follows appropriate USEPA guidelines including *Risk Assessment Guidance for Superfund* (RAGS) (1989) for human health and *Ecological Risk Assessment Guidance for Superfund* (ERAGS)*: Process for Designing and Conducting Ecological Risk Assessments* (USEPA, 1997) and *Guidelines for Ecological Risk Assessment,* (USEPA, 1998) for assessing risks to ecological receptors. In addition, all proposed work will be conducted in accordance with the *Project-Specific Quality Assurance Project Plan* (QAPP), and is provided in Attachment B.

1.1 Purpose and Objectives

The objective of this investigation is to collect environmental data to support CORCO in evaluating any potential human health or ecological impacts associated with chemicals of concern in soil, sediment, and groundwater at the nine areas of the site.

The specific objectives of this investigation are as follows:

- Collect soil, sediment, and ground water samples in nine selected areas of concern on the site;
- Samples will be analyzed for the following parameters:
    - Resource Conservation and Recovery Act (RCRA) metals;
    - Volatile organic compounds (VOC);
    - Semivolatile organic compounds (SVOC);
    - Polychlorinated biphenyl (PCB);
    - Total petroleum hydrocarbons (TPH); and,
    - Volatile petroleum hydrocarbon/Extractable petroleum hydrocarbons (VPH/EPH).
- Conduct an ecological risk assessment following ERAGS (USEPA, 1997);
    - Evaluate potential ecological risk to appropriate terrestrial receptors associated with each area of concern;
    - Evaluate potential risks to the giant land crab (*Cargidoma guanhumi)* in appropriate areas;

  - Evaluate potential risks to benthic communities that may be associated with the lagoons or effluent channel areas.

- Conduct a human health risk assessment following RAGS (USEPA, 1989; 2001).
  - Industrial worker – Adult Worker;
  - Utility Worker – Adult Worker;
  - Construction Worker – Adult Worker;
  - Recreational Visitor – Child and Adult;
  - Trespasser – Adolescent and Adult;
- Analytical data collected will also be used to develop the conceptual site model for human health and ecological exposures.

1.2 Summary of Proposed Samples

The soil samples collected to quantify exposures to human receptors focus on two depth intervals, a surface sample from zero to one foot below ground surface (bgs) and a deeper interval between 1 and 4 feet bgs. In addition, in certain areas that may be sold by CORCO to other owners, an even deeper 4 to 10 feet bgs sample interval will be collected. Groundwater samples will be collected to quantify potential human exposures to groundwater. To quantify exposure to ecological receptors, soil samples will be collected in the surface interval from zero to one foot bgs. Sediment samples will be collected from the biologically active zone (BAZ), which is typically represented by the zero to 6 inch range. Table 1 provides a summary of the samples proposed from each area of concern. The project will be carried out in phases based on general location with Phase 1 addressing eastern sites, Phase 2 addressing southwestern sites and Phase 3 including the central portion of the property.

The following activities are proposed:

1. Collect a total of 349 soil/sediment samples from the 9 areas of concern (broken into 18 sub-areas of concern below) to characterize potential ecological risks.
2. Collect a total of 444 soil samples from the 18 sub-areas of concern to characterize potential human health risks.
3. Collect approximately 60 groundwater samples from same number of groundwater wells to characterize potential human health risks. The exact number of wells samples will be based on wells without free product present at the time of sample collection.
4. Collect 19 surface water samples from the Western Lagoons, Jakes Lagoon and the Effluent Channel to characterize potential human health risks.
5. Table 1 includes a description of the sub-areas of concern divided into Phase 1, 2 and 3.

Table 1 Summary of Proposed Samples by Area of Concern and Environmental Media

SUB-AREAS OF CONCERN	SOIL/SEDIMENT SAMPLING DEPTHS				
	ERA Samples	HHRA Samples		HHRA Samples	HHRA Samples
	0-1 ft	1-4 ft	4-10 ft	Groundwater	Surface Water
Phase 1					
Eastern Lagoon	9[a]	9	9		
CIC Tanks	12	12	12		
Oxochem/CIC	18	18	18	TBD	
Tallaboa River	7[a]	--	--		
North of CPI 2	6	6	--		
Tallaboa Pipeline	20	20	20		
Phase 2					
Effluent Channel	5[a]	5	--		5
Jakes Lagoon	23[a]	12	--	TBD	5
Tank 1007	2	2	--		
Flores Park	32	23	--	TBD	
Western Lagoons	34[a]	17	--	TBD	9
Phase 3					
Pump Stations	29	29	--		
Demo Tanks	44	44	44		
Refinery	49	49	49		
S. Operational Tanks	10	10	--		
N. Operational Tanks	16	16	--		
Main Site Pipeline	20	20	--		
Main Site	13	--	--	TBD	
Totals:	349	292	152	Approx. 60	19

a. Sediment samples collected from this area of concern will be from the 0-6 inch interval.

2.0 DATA COLLECTION AND ANALYSIS

This section details the methods that will be used to perform the sampling and sample processing activities for the collection and analysis of soil, sediment, and groundwater samples. Sample method specific standard operating procedures (SOP) are provided in the QAPP, Attachment B.

2.1 Sample Design

Soil, sediment, groundwater, and surface water samples will be collected to support both an ecological and human health risk assessment. The objective of the sample design for soil and sediment samples is to provide adequate spatial coverage to quantify chemical exposures associated with each area of concern. Samples collected to support human health evaluation were biased toward areas where human activities are likely to occur. Similarly, samples collected to support the ecological assessment were biased to areas of suitable habitat for ecological receptors.

Wells in the existing groundwater well network in locations biased as per above criteria and that do not contain free product will be sampled.

2.1.1 Station Locations

The sampling design targets 9 areas throughout the site. Table 1 summarizes the number of samples proposed. Figures 5-9, 5-10, 5-15, 5-16, 5-21, 6-8, 7-5, and 8-5 of the RFI Work Plan illustrates the proposed sample locations for each of the areas of concern. Groundwater samples are illustrated in Figures 6-7 and 8-4 of the RFI Work Plan.

2.1.2 Sample Designation

Samples will be uniquely identified with a nomenclature that includes station ID and date. Stations will be identified by the area of concern, sample type, and number. Areas of concern will be designated by two-character identifier:

EL	=	Eastern Lagoon
PO	=	PR Olefins
OC	=	Oxo/CIC
RR	=	River
CI	=	N CPI 2
EF	=	Effluent Channel
JL	=	Jakes Lagoon
T7	=	Tank 1007
TP	=	Tallaboa Pipeline
PS	=	Pump Stations
DT	=	Demo Tanks
RF	=	Refinery

ST = S. Operational Tanks

NT = N. Operational Tanks

FP = Flores Park

WL = W. Lagoon

MP = Main Site Pipeline

MS = Main Site

The sample type code indicates the environmental media sampled and is identified by a two characters.

SS = Soil

SD = Sediment

SW = Surface Water

GW = Groundwater

Quality control and quality assurance samples, such as rinsate and trip blanks will not require a station identifier. The date the sample is collected will be included in each sample ID, and will be an eight-character code in the format YYYYMMDD.

Example Sample ID: FPSS01-20130816

This sample ID indicates that a soil sample was collected from Flores Park, sample 01, collected on August 16, 2013.

2.2 Field Documentation

All aspects of the field sampling activities will be documented in waterproof field logs or field data sheets. Information contained in the log book should include a summary of the daily activities and important milestones at each sample location. Information contained in the log book or on data sheets will include:

- Date and time of each activity;
- Weather conditions;
- Field team names and affiliations, and general work activities;
- Chronology of daily activities including daily safety briefing meetings, start time, and finish time in each area of concern;
- Log of sample locations and sample collection activities including a record of photographs, sample locations, and samples collected (including identification name); and,

- Other information considered relevant to the daily operations.

Station coordinates will be located using a handheld Global Positioning System (GPS) receiver fitted with a WAAS antennae (or dGPS equivalent) capable of an accuracy of ± 2 meters. Coordinates will be recorded as latitude and longitude in decimal degrees or degrees and decimal minutes (NAD 83). Prior to the survey, the GPS unit will be inspected and tested.

2.3 Soil Sample Collection Procedures

Soil samples will be collected using two methods; a surface soil method for the 0-1 ft sample interval and a soil boring method to collect the deeper intervals, 1-4 ft, and 4-10 ft.

The general procedure for collecting surface soil samples, 0-1 ft, is described below.

1. Proceed to the target sample station using the proposed coordinates and triangulation from visual landmarks as necessary. Care will be taken to approach the sample location without disturbing the soil to be sampled.
2. Record survey/GPS coordinates for each sample attempt on the Sample Collection Data Sheet.
3. Prepare labels, glassware, and chain of custody for station. In some cases the sampling container labels may be prepared ahead of time.
4. Don a clean pair of latex or nitrile surgical gloves and safety glasses.
5. Using a decontaminated spade or hand trowel, push away any leaf litter and debris. Soil sample will be collected down to a depth of 1 foot and placed in a decontaminated stainless-steel bowl and homogenized using the quartering procedure with a decontaminated stainless-steel spoon. For samples collected for VOCs analysis, care should be taken to minimize disturbance of the sample prior to placement into the sample containers (VOC samples are not homogenized).
6. Distribute the homogenized soil to appropriate sample containers, add preservatives if necessary, secure the container lids, and ensure that sample labels are completely and correctly filled out and affixed to the containers.
7. Clean the exterior of all sample containers and store in an ice chest at ≤4°C.

Equipment will be cleaned and decontaminated between sampling stations.

Prior to shipping, samples will be held in coolers with wet ice, ensuring that samples are held at ≤4°C. All other sampling methods and sample custody procedures will be conducted in a manner consistent with that of the QAPP.

The following procedures will be implemented to collect soil borings for deeper soil sample; 1-4ft and 4-10ft. Specific details regarding sediment collection and handling procedures are presented in the QAPP in Attachment B.

1. Proceed to the target sample station using the proposed coordinates and triangulation from visual landmarks as necessary. Care will be taken to approach the sample location without disturbing the soil to be sampled.
2. Record survey/GPS coordinates for each sample attempt on the Sample Collection Data Sheet.
3. Prepare labels, glassware, and chain of custody for station. In some cases the sampling container labels may be prepared ahead of time.
4. Don a clean pair of latex or nitrile surgical gloves and safety glasses.
5. Position the drill rig over the point to be sampled, and advance the boring first to a depth of 4' and remove the core.
6. Remove the core from the lining, and remove any vegetation that may be at the surface of the core. Homogenize sample using procedure outlined above.
7. Distribute the homogenized soil to appropriate sample containers, add preservatives if necessary, secure the container lids, and ensure that sample labels are completely and correctly filled out and affixed to the containers.
8. Clean the exterior of all sample containers and store in an ice chest at ≤4°C.
9. Decontaminate all sampling equipment following the collection of the 1-4 ft sample.
10. Advance the boring to a total depth of 10 feet.
11. Remove core from lining, and remove top few inches of soil from the core, as it may be wall material that sloughed off after removal of the 1-4 ft sample. Homogenize sample using quartering procedure.
12. Distribute the homogenized soil to appropriate sample containers, add preservatives if necessary, secure the container lids, and ensure that sample labels are completely and correctly filled out and affixed to the containers.
13. Clean the exterior of all sample containers and store in an ice chest at ≤4°C.
14. Prior to shipping, samples will be held in coolers with wet ice, ensuring that samples are held at ≤4°C. All other sampling methods and sample custody procedures will be conducted in a manner consistent with that of the QAPP.

2.4 Sediment Sample Collection Procedures

Sediment samples will be collected from an overhead crane, flat bottomed boat, plywood sheeting, or other appropriate means that will provide safe access to the Effluent Channel and

Western Lagoons. Prior to sampling, an inspection of the equipment will be conducted and will include an inventory of required safety gear (*e.g*, personal floatation devices).

Surface sediment samples will be collected at each station using a stainless-steel modified van-Veen or modified Ponar sampler; samples will be collected from the 0" to 6" interval below the surface. The volume of sample required for each analysis is presented in the QAPP, Worksheet #19.

The general procedure for collecting sediment samples using the grab samplers is described below.

1. Navigate the equipment to the target sample station as feasible. The equipment will be positioned at the target sample station using the proposed coordinates and triangulation from visual landmarks. Care will be taken to approach the station without disturbing surface sediments. Final location will be determined based on field observations and sediment availability.
2. Record survey coordinates for each sample attempt on the Sample Collection Data Sheet.
3. Prepare labels, glassware, and chain of custody for station. In some cases the sampling container labels may be prepared ahead of time.
4. Don a clean pair of latex or nitrile surgical gloves and safety glasses.
5. Using decontaminated sampling equipment, lower the modified Ponar sampler to the bottom by hand, taking care not to disturb surface sediments.
6. Once on the bottom, trigger the sampler and lift the sampler slowly to prevent washing of sediment from the sampler.
7. Open the sampler doors and determine whether the sample is acceptable (i.e., sediment penetration depth is adequate and there are no signs of washout or channeling of the sediment surface). If acceptable, the surface sediment grab sample will be retained for sample collection. At some stations several attempts may be required to obtain acceptable surface sediment volume. The sampling equipment will not be decontaminated between discrete samples for a given location. At each sampling station, sufficient volume will be collected for chemical and physical analysis and for archiving purposes.
8. Place sediment in a decontaminated stainless-steel bowl and homogenize the sediment/soil with a decontaminated stainless-steel spoon. For samples collected for VOCs analysis care should be taken to minimize disturbance of the sample prior to placement into the sample containers.

9. Distribute the homogenized sediment to appropriate sample containers, add preservatives if necessary, secure the container lids, and ensure that sample labels are completely and correctly filled out and affixed to the containers.
10. Clean the exterior of all sample containers and store in an ice chest at ≤4°C.
11. Excess sediment will be returned to the site at the approximate location of sampling.

Equipment will be cleaned and decontaminated between sampling stations.

Prior to shipping, samples will be held in coolers with wet ice, ensuring that samples are held at ≤4°C. All other sampling methods and sample custody procedures will be conducted in a manner consistent the QAPP.

2.5 Groundwater Sample Collection Procedures

The following procedures will be used to collect groundwater samples.

1. At least two weeks prior to sampling, the monitoring wells will be redeveloped using a surge block and pump until the discharge water appears to be free of entrained sediment.
2. Dedicated disposable polyethylene tubing will be used. Non-disposable equipment will be decontaminated between sampling locations to prevent cross-contamination.
3. Proceed to the target groundwater well. Wells are typically identified at the field.
4. If location coordinates are not available, record survey coordinates on the Sample Collection Data Sheet.
5. Prepare labels, glassware, and chain of custody for station. In some cases the sampling container labels may be prepared ahead of time.
6. Don a clean pair of latex or nitrile surgical gloves and safety glasses.
7. Samples will be conducted using the low-flow (low-stress) method of monitoring well purging and sampling.
8. A peristaltic pump will be used to purge the well at less than 300 ml/min with the intake placed in the middle of the standing groundwater column within the monitoring well.
9. While pumping, fluid level measurements will be taken to confirm that water levels within the wells do not change more than 0.20 ft using a cleaned electronic water level indicator.
10. The pump shall discharge through a flow-through cell where indicator parameters will be continuously monitored using a multi-parameter sonde (YSI 600 or

equivalent). These parameters will include turbidity, pH, reduction/oxidation potential, conductivity, and dissolved oxygen.

11. Measurements will be recorded on the Water Quality Field Data Log and maintained in a bound field logbook. Purging shall continue until turbidity has decreased to less than ten NTUs and other parameters have stabilized or nearly stabilized (asymptotic response).
12. The line into the flow through cell shall then be disconnected and the samples collected into appropriate sample containers defined in the QAPP.
13. Clean the exterior of all sample containers and store in an ice chest at ≤4°C.
14. Equipment will be cleaned and decontaminated between sampling stations.
15. Prior to shipping, samples will be held in coolers with wet ice, ensuring that samples are held at ≤4°C. All other sampling methods and sample custody procedures will be conducted in a manner consistent the QAPP.

2.6 Surface Water Sample Collection Procedures

The following procedures will be used to collect surface water samples from the Western Lagoons and Effluent Channel. Surface water samples will be co-located with sediment sample locations.

The general procedure for collecting surface water samples is described below.

1. Proceed to the target sample station using the proposed coordinates and triangulation from visual landmarks. Care will be taken to approach the sample location without disturbing the underlying sediment. For some sampling locations - particularly within the Western Lagoons - access may represent specific challenges (i.e., presence of apparently firm sediment layer, dense vegetation, long distance from shore to sampling location, etc.) that will need to be carefully addressed in advance from a safety standpoint.
2. Record survey/GPS coordinates for each sample attempt on the Sample Collection Data Sheet.
3. Prepare labels, glassware, and chain of custody for station. In some cases the sampling container labels may be prepared ahead of time.
4. All water samples will be collected prior to collecting sediment samples to avoid retaining suspended sediment in the water sample.
5. Record water quality measurements prior to collecting any sediment samples. Water quality observations will include dissolved oxygen, temperature, pH, salinity and turbidity (as NTU). Water quality measurements will be recorded on Sample Collection Data Sheet.

6. Don a clean pair of latex or nitrile surgical gloves and safety glasses
7. Surface water samples will be collected from approximately 2 feet above the sediment using a clean van Dorn sample bottle.
8. With the sampler doors open, lower the van Dorn sampler to the appropriate depth and record the sample depth on Sample Collection Data Sheet.
9. Once at depth, release the weighted messenger to trigger the sampler and retrieve the sampler.
10. The van Dorn sample bottle may need to be deployed several times to collect the volume of water necessary to conduct all of the planned analytical measurements.
11. The water sample will be transfer from the van Dorn sample bottle to the appropriate sample container as described in the QAPP.
12. In shallow areas accessible by wading, water samples may be collected directly into sample bottles.
13. Prior to shipping, samples will be held in coolers with wet ice, ensuring that samples are held at ≤4°C. All other sampling methods and sample custody procedures will be conducted in a manner consistent the QAPP.

Clean the exterior of all sample containers and store in an ice chest at ≤4°C.

Equipment will be cleaned and decontaminated between sampling stations.

Prior to shipping, samples will be held in coolers with wet ice, ensuring that samples are held at ≤4°C. All other sampling methods and sample custody procedures will be conducted in a manner consistent the QAPP.

2.7 Equipment Decontamination Procedures

All non-disposal sampling equipment that may come into contact with a sample, including sampling devices, bowls, and spoons will be decontaminated prior to sampling a new station using the following procedures:

1. Wash all surfaces with tap water and non-phosphate detergent (Alconox®) and scrub all surfaces with a brush or sponge to remove visual contamination.
2. Generously rinse all surfaces with tap water at least three times.
3. Rinse each surface with distilled/deionized water.
4. Allow equipment to dry.
5. Wrap clean equipment in aluminum foil until it is ready to be used.

6. Decontamination fluids and spent personal protection equipment (PPE) will be containerized as investigation derived waste (IDW). The decontamination fluids will be containerized separately.

2.7.1 Sample Equipment

The following list provides the minimum sample equipment and materials that will be used for this project:

- Stainless steel spade and hand trawl;
- Stainless steel ponar or van Veen grab sampler;
- Dorn sample bottles;
- Peristaltic pump and appropriate tubing for groundwater sampling;
- Hand-held GPS;
- Waterproof camera;
- Stainless steel compositing tools, spoons, spatulas, bowls;
- Alconox detergent;
- Deionized water;
- Acetone;
- Decontamination brushes and buckets;
- Analytical chemistry jars and labels;
- Tape and sharpies type pens;
- Waste storage containers and plastic trash bags;
- Sample handling materials including gloves, coolers, and chain of custody forms;
- Field documentation including waterproof field log, sample locations maps, the HHERAWP, and HASP, including emergency contact list; and,
- Cell phone or radio capable of call for help.

2.8 Training Requirements

All field team members will have OSHA hazardous waste operation working training as defined in 29 CFR 19190.120 and basic first aid training. At least two field team members will be trained in data documentation procedures and chain-of custody procedures.

Prior to commencement of field work, all field personnel will review the QAPP, HASP, and become familiar with the project scope of work and potential project risks. In addition, each field team member is required to read this project specific HHERAWP.

2.9 Investigation Derived Waste

The US EPA mandates the management of IDW to ensure protection of the environment and of human health. IDW from this project may include:

- Used personal protective equipment (PPE); sampling gloves, tyvek suits, shoe covers
- Packaging and storage materials, plastic bags, foil, DI water containers
- Liquids or solids from field decontamination procedures.

The field team will manage the individual waste streams in similar manners, with the goal to minimize the volume of IDW. The following procedures shall be used for the individual waste streams:

- Used PPE, disposable sampling equipment and package materials will be managed together and minimized whenever possible. These wastes are not considered hazardous and can be sent to a municipal landfill. These wastes will be stored within heavy duty, rip-stop trash bags until filled to 80% capacity. The bags will be compacted using manual pressure, standing air will be removed to the extent practical and the bags taped shut. If a bag contains sharp objects or there is a potential for the bag to rip, the bag will be isolated with an outer overpackbag.

- Decontamination fluids will include residual solvents, deionized water, a dilute solution (2% to 5%) of Alconox non-phosphate detergent, source water, and inherent sediment pore water and sediment solids. The three latter materials are generated from the site and the DI water and Alconox are approved for direct disposal to the environment. The decontamination fluid will be captured at each sample location. Decontamination fluids will be returned to the shore for subsequent storage followed by waste characterization sampling of the material. The ultimate disposal of decontamination fluids will be determined once the results of the waste characterization analysis are received.

3.0 SAMPLE HANDLING AND CHEMICAL ANALYSIS

All samples will be held in coolers with ice packs at ≤4°C prior to shipping to the analytical laboratories. Prior to shipping, samples IDs will be checked for completeness and to ensure that they have been entered into the field logs and chain of custody forms. All samples will be transferred to the analytical laboratories in coolers packaged for shipping using bubble wrap or other appropriate packaging. Sufficient ice or blue ice will be included to maintain the holding temperature (≤4°C).

4.0 CHAIN-OF-CUSTODY DOCUMENTATION

All members of the project team will follow the procedures for managing samples through the chain-of-custody (COC) format (Figure 2-2 of the QAPP). All information required for the COC will be captured within the field notes, site data sheets and/or field book by the sampling scientist. The sampling scientist will maintain physical possession of all samples while

conducting field activities. Prior to completion of each work day, the sampler shall prepare a COC describing each sample container within each sample cooler. The following minimum information will be included on each COC:

- Project name;
- Sampler's name and contact information including phone number and e-mail address;
- Sampler's company affiliation;
- Unique sample name for each sample;
- Sample date;
- Quantity of sample containers;
- Preservatives;
- Volume of sample or sample container;
- Number of sample containers;
- Optionally, the COC may include the type of sample that was collected, such as a "normal" sample, a duplicate sample, a spiked sample, a field blank, a rinsate blank, a trip blank, etc;
- Analysis requested or handling procedures for each sample;
- Information on laboratory receiving the samples:
    - Contact name at the receiving destination
    - Phone number and e-mail for receiving destination
    - Note for special handling or special instructions; and,
- Table of sample control documenting each person to receive and relinquish the cooler and a notation of whether the COC includes containers in multiple coolers or only one cooler.

At least one copy of the chain-of-custody form shall be included within each sample cooler. The sample team may elect to capture all site information within an electronic COC format. If selected, all information within the electronic COC will be duplicated within the field book or field notes. Also, at least 2 copies of the COC will be printed at the time the sample coolers are packaged; one for record purposes and one for transportation with each sample cooler.

5.0 HUMAN HEALTH RISK ASSESSMENT METHODOLOGY

The purpose of this section is to identify the methodology to be used to determine the data set used in the HHRA and to identify the HH COPCs for the Site. HH COPCs are chemicals/constituents that exist in the environment at concentrations of potential concern to the health of humans.

5.1 Data Evaluation

Before HH COPCs can be selected, a risk evaluation data set must be developed. To develop the data set, data evaluated for the Site media that are determined to be of sufficient quality will be used in the risk evaluation. The evaluation process includes evaluating sample collection,

handling, analysis, and quality control procedures as well as previous data quality evaluations performed by other investigators or data users when available, consistent with those prescribed in the RAGS (Part A) and Guidance for Data Usability in Risk Assessment (Part A). Detection limits of the samples are also compared to the applicable screening levels (RSLs) as part of the data usability evaluation, thus ensuring that no HH COPC would be screened out due to lack of detection using an analytical method with an elevated detection limit. The HHRA report will provide a summary of the data of appropriate quality used to complete the risk assessment, including chemical, exposure, spatial, and temporal representativeness of the data.

5.2 Site-Specific Background Values

Background considerations may be incorporated into the assessment and investigation of sites, as acknowledged in existing EPA guidance - *Role of Background in the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) Cleanup Program* and *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites*. The guidance indicates that, although background should not be considered in identification of HH COPCs or ultimately the chemicals of human health concern, it should be considered in risk characterization. The HHRA will include an evaluation of currently available Site-specific reference levels consistent with this guidance as a line-of-evidence.

5.3 Chemicals of Potential Concern Selection

In order to focus efforts of the HHRA COPCs will be screened against risk-based EPA Regional Screening Levels (RSLs). COPCs for which maximum detected concentrations exceed the screening levels will be identified as HH COPCs and retained for further analysis in the risk assessment.

Although future land use will likely not be residential, residential screening values will be used as the screening level since they are conservatively protective of general use of the Site. The use of residential screening values offers a significant degree of protection for other potential future receptors, such as industrial, recreational, and trespassers. These levels are appropriate for conservatively identifying HH COPCs in a risk assessment.

The toxicity-based criteria that will be used in the screening evaluation to identify HH COPCs will include:

EPA's Regional Screening Levels (RSL) for Chemical Contaminants at Superfund Sites (May 2013) for groundwater;

EPA's Ambient Water Quality Criteria (AWQC) (2012) for organism consumption and EPA's "RSL for Chemical Contaminants at Superfund Sites" (May 2013): the lesser of the RSL screening level value selected for groundwater or AWQC for surface water; and

EPA's RSL for Chemical Contaminants at Superfund Sites (May 2013) for residential soil exposure for soil and sediment.

The RSL screening levels for each COPC will correspond to the lesser of the 10-6 risk level for its carcinogenic effect or a hazard quotient (HQ) of 0.1 for its non-carcinogenic effect. Therefore, if the RSL is based on a non-carcinogenic effect, the RSL will be divided by 10 the May 2013 RSL table includes these 0.1 HI values if the RSL is based on a carcinogenic effect it was reported as listed on the RSL table. If a COPC has both a carcinogenic effect and a non-carcinogenic effect, the effect not reflected on the RSL will be determined and will also be listed on the HHRA screening level table for Screening Level purposes. For surface waters the AWQC concentration will be used as published.

The following overall steps will be used in identifying HH COPCs:

The maximum concentration for each COPC detected on the Site will be compared to appropriate screening levels for soil, surface water, sediment, and groundwater. COPCs are identified as any constituent analyzed for at the Site. COPCs for which the maximum concentration exceeds screening levels will be retained for further analysis as a HH COPC.

Any COPC that is not positively detected in 5% of the samples (minimum of 20 samples per COPC) will be excluded. However, prior to final exclusion, the distribution of the detections will be assessed to determine if the samples represent a "hot spot" or a small area of high concentrations. If a hot spot is determined to be present, the COPC will be retained as a HH COPC. Those COPCs with fewer than 20 samples will not be excluded unless they have never been detected.

Any COPC detected at concentrations less than the applicable toxicity-based screening level will not be retained as a HH COPC.

Any COPCs that were detected in at least one sample and do not have a screening level, will be retained for further analysis.

Any soil HH COPC will also be used as the HH COPCs selected for air-entrained particulates.

6.0 EXPOSURE ASSESSMENT

A human health conceptual site model (HH CSM) will be developed to identify the means by which humans may be exposed to Site contaminants and includes:

- Primary and secondary sources;
- Mechanisms of HH COPC releases from these source areas;
- Exposure media;

- Routes of exposure; and
- Exposure receptors.

The HH CSM will provide a preliminary assessment of which exposure pathways are (1) complete, (2) potentially complete but probably result in insignificant exposure, or (3) incomplete exposure pathways, consistent with EPA guidance.

6.1 Exposure Media

The potential exposure media at the Site include:

- Soil and the associated derived air particulates;
- Impoundment water in lagoons;
- Sediments in lagoons;
- Groundwater;
- Indoor vapor from vapor intrusion (volatiles in soil and/or groundwater).

6.2 Potentially Exposed Populations

The following receptor populations have been preliminarily identified for use in this HHRA.

Industrial worker – Adult worker. Exposure scenario is both current and future.

Utility worker – Adult worker. Exposure scenario is both current and future.

Construction worker – Adult worker. Exposure scenario is both current and future.

Recreational visitor– Child and adult. Exposure scenario is both current and future

Trespasser - Adolescent and adult. Exposure scenario is both current and future.

6.3 Exposure Pathways

The exposure pathways potentially considered for all receptor groups include:

- Incidental ingestion and dermal contact with soil;
- Incidental ingestion of and dermal contact with lagoon and effluent channel water;
- Ingestion of giant crabs;
- Incidental ingestion and dermal contact with sediments in lagoon and effluent channel;
- Ingestion of and dermal contact with groundwater;
- Inhalation of vapors (vapor intrusion) from volatiles present in soil and/or groundwater;
- Inhalation of particulates derived from soil.

In accordance with EPA guidance, only potentially complete exposure pathways will be evaluated. To be potentially complete, the four primary elements of an exposure pathway must be complete at the Site: source or sources, release and transport mechanisms, exposure media, and receptors. Incomplete exposure pathways will not be evaluated further in the risk assessment. Complete but insignificant exposure pathways are believed to not add appreciable risk relative to other complete exposure pathways and therefore will not be assessed quantitatively but will be discussed qualitatively. A preliminary assessment of the status of the exposure pathways will be included in the HH CSM.

6.4 Quantification of Exposure

The amount of a chemical that is ingested, inhaled, or taken up across the skin is referred to as "intake" or "dose" and is usually calculated using an equation of the following general form.

$$DI = C \cdot \left(\frac{IR}{BW} \right) \cdot \left(\frac{EF \cdot ED}{AT} \right)$$

where:

DI = Daily intake of chemical (mg of chemical per kg of body weight per day; mg/kg/day).

C = Concentration of the chemical in the contaminated environmental media (soil, air, etc.) to which the person is exposed. The units are mg of chemical per unit of environmental medium (e.g., mg/kg for soil or dietary components, mg/L for waters, and mg/m^3 for air).

IR = Intake rate of the contaminated environmental medium. The units are usually kg/day for solid medium (soil, sediment, diet), L/day for waters (surface or groundwater) and m^3/day (air).

BW = Body weight of the exposed person (kg).

EF = Exposure frequency (days/year). This describes how often a person is likely to be exposed to the contaminated medium over the course of a typical year.

ED = Exposure duration (years). This describes how long a person is likely to be exposed to the contaminated medium during their lifetime.

AT = Averaging time (days). This term specifies the length of time over which the average dose will be calculated. Usually, two different averaging times are considered. "Chronic" exposure includes averaging times on the scale of years based on the exposure duration. Chronic averaging times are used when assessing non-cancer risk from HH COPCs. "Lifetime" exposure employs an

averaging time of 70 years. This lifetime exposure interval is selected when evaluating cancer risks.

The last three factors (EF, ED, AT) combine to yield a factor between zero and one. Values near one indicate that exposure is nearly continuous over the specified averaging period, while values near zero indicate that exposure occurs only rarely. Specific equations for complete exposure routes will be included in the HHRA.

The one exception to using the above approach to evaluate exposure is assessing the risk due to exposure to lead. Specialized exposure assessment approaches, Adult Lead Model (ALM) model and the Integrated Exposure Uptake Biokinetic Model (IEUBK model) for adults and children, respectively, will be discussed and presented if lead is selected as a HH COPC. Given many of the Site's receptors have intermittent exposure and the EPA lead models are designed for steady-state exposures, EPA's guidance on variable and intermittent exposure at lead sites will also be used.

To quantify exposure using the above equation, each receptor's exposure will be estimated using exposure parameters and the concentration of the HH COPC in the environmental media (soil, air, etc.) or exposure point concentration (EPC) needs to be determined.

6.4.1 Exposure Parameters

To assess the daily intake of each receptor group, exposure intake parameters need to be selected to quantify the intake from each complete exposure pathway. These intake factors will be selected for both a reasonable maximum exposure (RME) and a central tendency exposure (CTE). The RME is the maximum exposure that is reasonably expected to occur at the Site. Intake parameter values will be selected so that the combination of all parameters results in an estimate of the RME for a particular exposure pathway. By design, the estimated RME is higher than that expected to be experienced by most of the exposed population. As recommended in *Guidance for Risk Characterization*, CTE estimates represent the central estimates of exposure or dose. The CTE estimate is intended to be more representative of likely human exposures.

Exposure parameters will be developed for potentially complete exposure pathways and receptors based on EPA guidance documents and professional judgment. The latest exposure factor handbook (2011) will be used as the primary source of exposure parameters. All exposure estimates will be based on standard equations derived for each exposure media from the general intake equation above.

The receptor populations will be divided into three age groups, children (0 to <6 years), adolescent (6-16 years), and adult (16 years or older), rather than the two typical groups (child and adult) considered in most human health risk assessments. The adult and child receptors will be considered for all exposure scenarios except the trespasser scenario; adolescents and

adults will be evaluated for this scenario due to the higher likelihood of the adolescent to trespass.

Cancer and non-cancer risks will be initially assessed using RME estimates for the primary exposure pathways and selected receptors. If the RME estimate exceeded the target risk levels, then CTE estimates will be calculated for comparison purposes.

6.4.2 Exposure Point Concentrations and Exposure Domain

After selection of HH COPCs, Exposure Point Concentrations (EPCs) will be derived for each medium of concern within each receptor's appropriate exposure domain. The exposure domain is defined as the area of the Site to which the receptor is exposed. Exposure domains will be identified based on the activities or actions of the receptor. Some receptors will be assessed on a Site-wide basis, whereas, others may be defined based on a limited Site exposure scenario developed through an evaluation of potential land use. Exposure areas or domains may vary by medium for a given receptor.

For each exposure domain, the EPC will be calculated as the 95th upper confidence limit (95UCL) (alpha = 0.05) of the arithmetic mean concentration. EPA's most current statistical program and guidance (ProUCL 4.1) will be used to calculate the 95UCL. ProUCL provides guidance and a range of parametric and non-parametric methodology for handling datasets of different distributions, left-censored datasets, identification of outliers, datasets with non-detect values, and treatment of datasets with small sample sizes. The appropriate ProUCL method ultimately used will depend on the characteristics of each data set and will be documented in the HHRA report.

For Tier 1, the exposure domain will be defined as the entire Site and all sample results from within the Site will be used to establish a Tier 1 EPC for each medium. Source materials, non-source soils, and sediments will be combined together, with all samples weighted equally in calculating the EPC. This step is intended as a "screening" step to identify the COPCs for which more detailed analysis is needed.

In Tier 2, the EPC will be focused on the areas of the Site that the receptors are most likely to use, and where there is a higher chance of receptors contacting affected media. The exposure domains of some receptors are expected to be either less than the entire Site or weighted based on frequency of exposure to specific areas of the Site and will be adjusted based on information obtained from facility personnel regarding Site activities. Tier 2 risk characterization may include multiple exposure domains for each receptor group to help identify areas of the Site that require risk management action. A Site-wide exposure domain will be included for each receptor. The Tier 2 EPCs for soil and sediments will be based on a spatially weighted EPC for each exposure domain. The spatial weighting is intended to account for a higher density of sampling certain areas of the Site.

For lagoon and effluent channel water and sediment, the EPCs will be derived using the equally weighted samples from the media within the exposure domain and will only be spatially weighted if it is determined that one feature is potentially dominating the EPC.

Drinking water EPCs will be derived from data collected from selected groundwater wells that are believed to sustain sufficient water supply to be used as drinking water sources. The most current set of Site-wide groundwater monitoring will be used as the groundwater sample set.

For dietary exposure media (giant crabs), a weighting factor of 1.0 will be used in Tier 1 to indicate that all dietary sources are presumed to be solely Site-derived. However, in Tier 2 Site-specific weighting factors may be determined to modify dietary intakes, if appropriate, based on interviews and information attained during investigation.

7.0 TOXICITY ASSESSMENT

The toxicity assessment determines the relationship between the magnitude of exposure to a HH COPC and the nature and magnitude of adverse health effects that may result from such exposure.

Toxicity values that will be used in the HHRA will be obtained from EPA's risk-based concentration table and are selected using the following hierarchy of EPA sources:

The Integrated Risk Information System (IRIS), an electronic database containing health risk and EPA regulatory information on specific chemicals (http://www.epa.gov/ncea/iris/index.html).

The Provisional Peer Reviewed Toxicity Values (PPRTVs) derived by EPA's Superfund Health Risk Technical Support Center (STSC) for the EPA Superfund program.

The Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs).

The California Environmental Protection Agency/Office of Environmental Health Hazard Assessment's toxicity values.

The Health Effects Assessment Summary Tables (HEAST), provisional criteria compiled by the EPA Office of Solid Waste and Emergency Response (EPA, 1997b).

Toxicity values obtained from IRIS were given priority over all other sources as recommended by EPA. IRIS is the official EPA repository of agency-wide consensus human-health information.

8.0 RISK CHARACTERIZATION AND UNCERTAINTY

Risk characterization combines HH COPC toxicity information, exposure point concentrations, and exposure assumptions, to develop risk estimates. Cancer and non-cancer risks are assessed separately in accordance with EPA guidance to provide estimates of incremental cancer risks and indices for potential non-cancer hazards. Complete risk characterization also includes a discussion of uncertainties associated with the various steps of the risk assessment.

Cancer Risk - The risk of cancer from exposure to a chemical is described in terms of the probability that an exposed individual will develop cancer due to that exposure by age 70. This value is calculated from the daily intake of the chemical from the Site, averaged over a lifetime (DIL) and the slope factor (SF) for the chemical, as follows (EPA, 1989):

$$\text{Cancer Risk} = 1-\exp(-\text{DIL} \times \text{SF})$$

In most cases (except when the product of DIL×SF is larger than about 0.01), the following may accurately approximate this equation:

$$\text{Cancer Risk} = \text{DIL} \times \text{SF}$$

Excess cancer risks are summed across all HH COPCs that have a carcinogenic effect and all exposure pathways that contribute to exposure of an individual in a given population.

The level of total cancer risk that is of concern is a matter of personal, community, and regulatory judgment. In general, the EPA considers excess cancer risks that are below about 1E-06 (1 in 1,000,000 people may contract cancer) to be so small as to be negligible, and risks above 1E-04 (1 in 10,000 people may contract cancer) to be sufficiently large that some sort of remediation may be desirable. Cumulative excess cancer risks that range between 1E-04 and 1E-06 are considered to be acceptable by the EPA, although this is evaluated on a case-by-case basis.

Non-cancer Risk - The potential for non-cancer effects from exposure to a chemical will be evaluated by comparing the estimated daily intake of the chemical over a specific time period with the reference dose (RfD) for that chemical derived for a similar exposed period. This comparison results in a non-cancer HQ, as follows:

$$HQ = DI/RfD$$

where:

HQ = Hazard Quotient

DI = Daily Intake (mg/kg-day)

RfD = Reference Dose (mg/kg-day).

If the HQ for a chemical is equal to or less than one, it is believed that there is no appreciable risk that non-cancer health effects will occur. If a HQ exceeds one there is some possibility that non-cancer effects may occur, although a HQ above one does not indicate that an effect will definitely occur. This is because of the margin of safety inherent in the derivation of all RfD values. However, the larger the HQ value, the more likely it is that an adverse effect may occur.

Initially, HQs for all HH COPCs with noncancer effects will be added together for a cumulative Hazard Index (HI). If this cumulative HI is greater than 1.0 and more than one chemical affects the same target tissue or organ system (e.g., the liver), then the total risk of adverse effects in that tissue (HI for that issue) will be estimated by summing the HQ values for all chemicals that act on that tissue.

8.1 Background Comparison

For each receptor intake calculation and resulting risk, a corresponding intake and resulting risk will be calculated using the same exposure parameters and the HH COPC's background concentration, as discussed in Section 5.2, as the EPC. This comparison will allow for an evaluation of the incremental risk versus "measured" risk.

8.2 Human Health Tiered Risk Characterization Approach

The tiered approach in which generic assumptions and models are replaced, as necessary, by more realistic assumptions and models is generally accepted as a valid means to ensure that risk assessment results provide appropriate support for effective risk management. The Tier 1 assessment will be used to identify specific exposure scenarios and HH COPCs that can be eliminated from further consideration because they are associated with cumulative hazards less than 1 and cumulative risks less than 1E-05. In addition, specific HH COPCs will be eliminated from further consideration if it is associated with an individual HH COPC HI less than 0.1 and individual HH COPC risk less than 1E-06. In Tier 1, the EPCs will be the 95UCL of the HH COPC concentrations within a Site-wide exposure domain and the receptor's exposure parameters will be the RME. For areas/pathways where these target levels were exceeded, a Tier 2 assessment will be performed. Tier 2 risk characterization will be evaluated using spatially weighted EPCs as described in Section 6.4.2. In addition to evaluating the RME conditions, Tier 2 will evaluate CTE conditions.

The Tier 1 relies upon uniformly conservative default exposure and toxicity assumptions and models to ensure that no potential risk/hazard to the defined receptor populations could be overlooked or underestimated. While Tier 1 results cannot be construed as quantitative indicators of risk, this tier does effectively focus attention on those areas and exposure pathways requiring further investigation.

Background concentrations will also be evaluated during each tier under RME conditions. This comparison of background conditions to impacted conditions will be made for the uncertainty analysis. Site exposure risks that do not pass the tier's screen but are equivalent to background risks will be evaluated to determine whether they should continue into the next tier's assessment.

For any HH COPCs/exposure pathways that exceed a tier's target risk/hazard levels, the next tier's assessment will be performed, unless determined to be background risks. Tiers 3 and above assessments will be a refinement of the receptor's exposure based on information and Site observations (e.g., domain variations as described in Section 6.4.2 and fraction of Site-derived media estimations for dietary estimations in particular).

8.3 Uncertainty

The multiplicative nature of conservative assumptions used in risk calculations tends to overestimate risk. Sources of uncertainty will be discussed in the risk assessment report.

8.4 Development of Risk Management Guidelines

Guidelines for risk management of any identified HH COPCs could be developed as a result of the HHRA. Analyses will be based on the Tier 2 findings of the HHRA. For example, risk-based concentrations (RBCs) could be back-calculated based on an overall target cancer risk of 1 in 100,000 (10^{-5}) and also for 1 in 10,000 (10^{-4}) for the Site's HH COPC carcinogens and could be used to identify areas that may need selected remediation to reduce the overall risk of future exposures.

9.0 ECOLOGICAL RISK ASSESSMENT METHODOLOGY

The following sections describe the elements that will be included as part of the ecological risk assessment at the CORCO Facility. As previously mentioned, the approach will follow USEPA ERAGS guidelines (USEPA, 1997, 1998).

9.1 Data Collection and Synthesis

Upon completion of the data collection activities, analytical analysis, and data validation, the data will be compiled by environmental media and by each area of concern. Data will be organized into a GIS system to allow analysis of the chemical results. These data will be used to investigate the nature and extent of chemical concentrations, derive exposure point concentrations, and inform the development of Problem Formulation. An overview of the data used for this ecological risk assessment will be provided as part of this assessment.

9.2 Problem Formulation

The ecological risk assessment process begins with the problem formulation step and the development of a conceptual site model (CSM). The CSM integrates potential sources of contamination, fate and transport, pathways of exposure, and identifies the ecological receptors of concern. This provides the framework for connecting ecological receptors to contaminated media and determines the degree of completion and significance of exposure pathways. There are five main elements of the problem formulation:

1. Describing the environmental setting and contaminants that are known or suspected to exist;
2. Describing the fate and transport mechanisms that might exist at the site;
3. Ecotoxicity of contaminants and potentially affected ecological receptors;
4. Identifying the potentially completed exposure pathways; and,
5. Selecting endpoints to screen for ecological risks.

The environmental setting element will provide a summary of the analytical results of this program and a description of the nature and extent of the any contaminated media. The fate and transport element will focus on potentially contaminated environmental media including, soil, sediment, and groundwater. This will include the potential for direct exposure to contaminants in the soil and sediment and will examine the potential for groundwater to infiltrate to adjacent habitat areas such as the river, lagoons, or the effluent channel.

An understanding of the contaminant mechanism of toxicity is necessary to evaluate the importance of potential exposure pathways and to identify the appropriate selection of assessment endpoints. In addition, ecological receptors will vary in their toxicological response to contaminant exposure. This element of the problem formulation will discuss the ecotoxicological of the major categories of chemicals of potential ecological concern (COPEC). The types of ecological receptors to be considered will also be presented.

The exposure pathway element of the problem formulation step describes the route(s) a chemical may take from its source to an ecological receptor of concern. An exposure pathway analysis links the source, location, and type of environmental release with population, location, and activity patterns to determine the primary means of potential exposure. If potentially complete and significant exposure pathways exist between COPECs and the receptors, an assessment of potential effects and exposures is conducted. Only those potentially complete exposure pathways likely to contribute to the total exposure are quantitatively evaluated. All other potentially complete exposure pathways that result in minor exposures or for which there are no exposure models or insufficient toxicity data are not quantitatively evaluated.

An exposure pathway is considered complete if all four of the following elements are present (EPA, 1997):

1. A source and mechanism of chemical release to the environment.
2. An environmental retention or transport medium (*e.g.*, soil or sediment) for the released chemical.
3. A point of potential physical contact of a receptor with the contaminated medium (exposure point).
4. An exposure route (*e.g.*, ingestion of contaminated prey, incidental ingestion of soil).

In the absence of links between each of these elements, a complete exposure pathway cannot exist, and no risk to ecological receptors is possible. A CSM provides the logical framework to identify complete exposure routes.

Following identification of completed exposure pathways and receptors of concern, assessment and measurement endpoints (ME) will be determined. Risk assessment endpoints (AE) are defined by USEPA (1997) as formal expressions of the actual environmental values that are to be protected at a site. AEs are defined based on technical considerations, including the significance of exposure pathways, the presence of ecological receptor of concern, and a COPEC's biotic transfer pathway. Selection of AEs for use in the risk assessment must consider the ecosystem, communities, and species relevant to a particular site. The selection of AEs depends on:

1. The chemicals present and their concentration;
2. Mechanisms of toxicity of the chemicals to different groups of organisms;
3. Ecologically relevant receptor groups that are potentially sensitive or highly exposed to the chemicals; and,
4. Potentially complete exposure pathways.

For each AE specific MEs are defined. The MEs are measurable ecological characteristics, which can be measures of effect, such as community diversity or toxicity test results, or the ME can be a measure of exposure, such as a chemical concentration in soil. The MEs are used to evaluate the whether there is an adverse response to a site contaminant.

9.3 Contaminants of Potential Ecological Concern (Screening Process)

A two-tiered screening process is proposed to select COPECs for soil and sediment. The first step compares chemical concentrations to established, conservative benchmarks. Those compounds that did not exceed the media-specific ecological toxicity threshold are not evaluated any further. Those that do exceed the screening benchmarks are carried forward to the refined screening step. Those compounds that are detected, but there are no available benchmark are carried forward and discussed in the uncertainty section.

The second tier in the screening process considers the frequency and magnitude of COPEC detections. For soil and sediment the bioaccumulation potential is also considered. For those compounds retained from the first tier, the frequency of detects is evaluated. If the frequency of detection is less than 5% and the detection limits are below the screening criteria the compounds is evaluated further with respect to magnitude of exceedance. If any individual COPEC concentration is 5 times or greater than the screening threshold the compound is retained regardless of the frequency of detection. A compound is also retained if it is considered to be bioaccumulative. A compound may be removed from further evaluation if it is considered an essential element; this includes calcium, iron, magnesium, potassium, and sodium. The results from this screening process are assessed in the risk characterization step.

9.4 Ecological Risk Characterization

The risk characterization combines the exposure and effects assessments to quantitatively estimate the potential risks to the ecological receptor groups. The concentrations of chemicals in the environmental media (*i.e.,* soil and sediment) that ecological receptors are exposed to are referred to as the "exposure point concentrations" (EPC). The EPCs are then compared to toxicological threshold values to derive a hazard quotient (HQ) as described in Equation 1.

HQ = EPC/ecotoxicity threshold

To represent the exposure a receptor may encounter, the 95% upper confidence limit (95% UCL) on the mean may be calculated were sample size is appropriate using the current version of ProUCL. For areas were the sample size does not allow for the derivation of a 95% UCL, a sample point by sample point comparison will be used to estimate risk in a given area of concern. HQs will be derived for each environmental media using ecological based toxicity thresholds appropriate for the group of receptors being evaluated.

To characterize risks to higher trophic level receptors, such as avian or small mammalian receptors a food web model, often referred to as a dose model, is used. A contaminant specific dose is calculated using conservative values to estimate exposures to contaminants, such as food ingestion rates and portion of diet that is considered contaminated; Equation 2.

$$Dose = \frac{(C_{sed} * DI_{sed}) + (C_{fish} * DI_{fish}) * CF * SUF}{BW}$$

where:

Dose = average daily chemical dose to receptor (mg/Kg-d)

C_{sed} = chemical concentration in the sediment/soil (mg/Kg)

DI_{sed} = daily incidental ingestion of sediment/soil (Kg/d)

C_{prey} = estimated chemical concentration in prey item (mg/Kg)

DI_{prey} = daily ingestion of prey item (Kg/d)

CF = portion of diet considered contaminated (set = 1.0)

SUF = site use factor (area of exposure/range) (set at 1) (unitless)

BW = receptor body weight (Kg)

Chemical specific HQs are derived from the resulting daily dose and toxicity reference values (TRVs) using Equation 3.

HQ = Dose/TRV

where:

Dose = specific to each receptor and calculated using Equation 5 (mg/Kg^{-d})
TRV = species and constituent appropriate toxicity reference value (mg/Kg^{-d})

For the dose model, a low and high TRV, based on a no-observed adverse effect level (NOAEL) and a lowest observed adverse effect level (LOAEL), respectively, will be used. The application of the low and high TRV can provide a context and bounds on potential risk levels.

The risk characterization will be provided for each ecological receptor group of concern and for each area of concern. The magnitude and extent of the risks estimates will be provided.

9.5 Uncertainty Analysis

The uncertainty analysis discusses limitations and uncertainties of the risk assessment and the sources of uncertainties; it also assesses whether these uncertainties and limitations may have resulted in an over- or under-estimation of risk. The limitations and uncertainty is typically discussed as it relates to the following elements of the risk assessment process:

- Problem formulation, including identification of COPECs and exposure pathways;
- Ecological exposure assessment, including exposure parameters used in the dose model;
- Ecological Effects Assessment, including the TRV data and ecotoxicity data; and,
- Data gaps or unavailable information such as the lack of ecological toxicity information for specific compounds.

The uncertainty analysis is used to assess the confidence in the risk characterization given the limitations that are inherent in the data and assessment process.

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Figure 1 Example COC Form